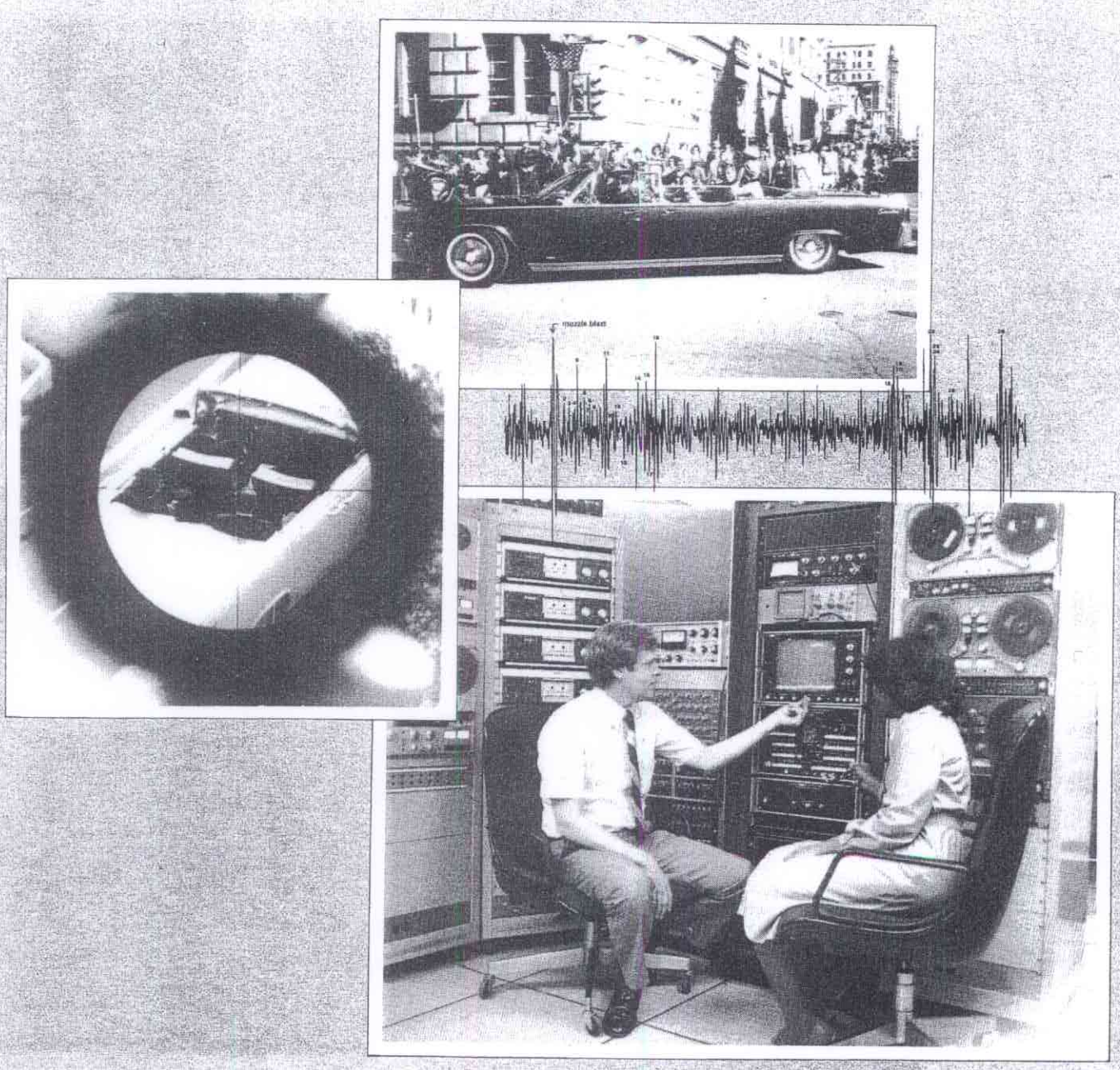
FBI LAW ENFORCEMENT BULLETIN



Acoustic Gunshot Analysis

The Kennedy Assassination and Beyond

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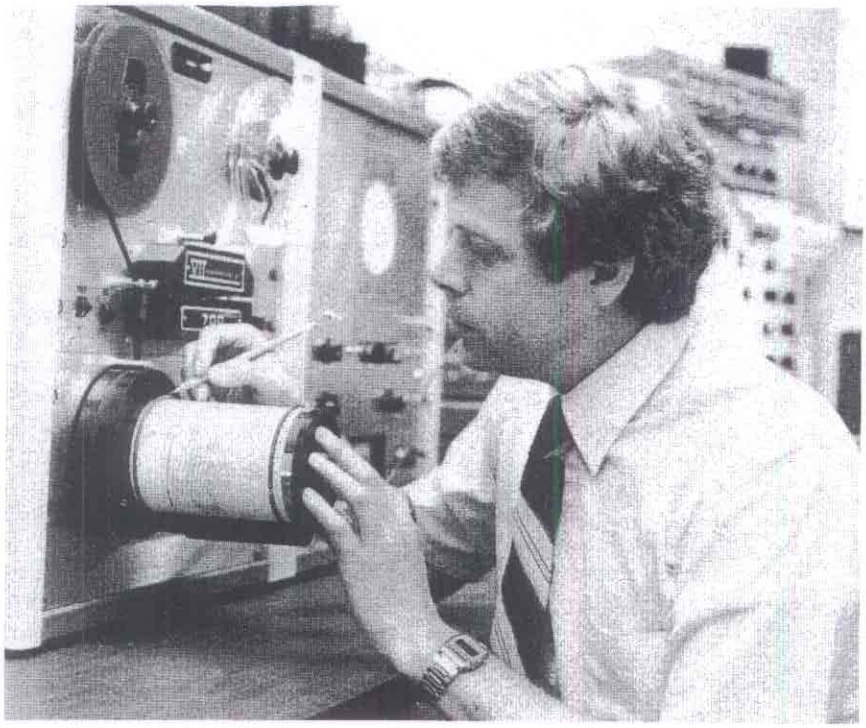

Acoustic Gunshot Analysis

The Kennedy Assassination and Beyond

(Conclusion)

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FBI Review

On November 19, 1980, the Technical Services Division of the FBI released a written review that was very skeptical of the acoustical reports prepared for the House Select Committee on Assassinations (HSCA). The review was limited to the written and oral reports prepared by Bolt Beranek and Newman (BBN) and Weiss and Aschkenasy for the HSCA, and no direct examinations of the Dallas Police Department (DPD) recordings were conducted. The findings of the FBI questioned the analyses of the acoustical evidence by BBN and Weiss and Aschkenasy, revealing that they did not prove scientifically that another person fired a gunshot from the grassy knoll in Dealey Plaza or that the recording of DPD's channel 1 contains gunshot sounds or any other sounds originating in Dealey Plaza during the assassination. The FBI's review stated that the HSCA's findings that "scientific acoustical evidence established a high probability that two gunmen fired at President John F. Kennedy" is invalid.[16]

The FBI's conclusion was based on a thorough review of the written findings and oral testimony of BBN and Weiss and Aschkenasy. For the HSCA's acoustical reports to be accurate, the FBI determined that two basic underlying premises would have to be correct:

1) The specified impulsive information recorded on channel 1 must have originated in or very

Special Agent Koenig

near Dealey Plaza. If this is not true, the information analyzed could not have been generated within Dealey Plaza, invalidating the findings concerning the gunshots fired during the Presidential assassination.

2) The four specified impulsive patterns identified by BBN on the DPD recording are gunshot blasts and not other sounds or electrical impulses produced internally by the DPD radio system. The third designated impulse pattern was the only one used by Weiss and Aschkenasy. If this premise is not true, the information analyzed did not represent gunshots, also invalidating the findings concerning possible gunshots fired during the Presidential assassination.[17]

There are at least three known methods that could determine whether the four specified impulsive patterns on the DPD recording originated from Dealey Plaza. If it can be shown acoustically that the other information on the DPD recording just before, during, and just after the pertinent time period was exclusively from Dealey Plaza, there is a very high probability that the four impulsive patterns also represent sounds produced in Dealey Plaza. It can also be acoustically proven that the patterns represent sounds from Dealey Plaza if the information being analyzed is unique to Dealey Plaza, to the exclusion of all other locations within the range of the DPD radio system. The third method requires proof from eyewitness testimony.

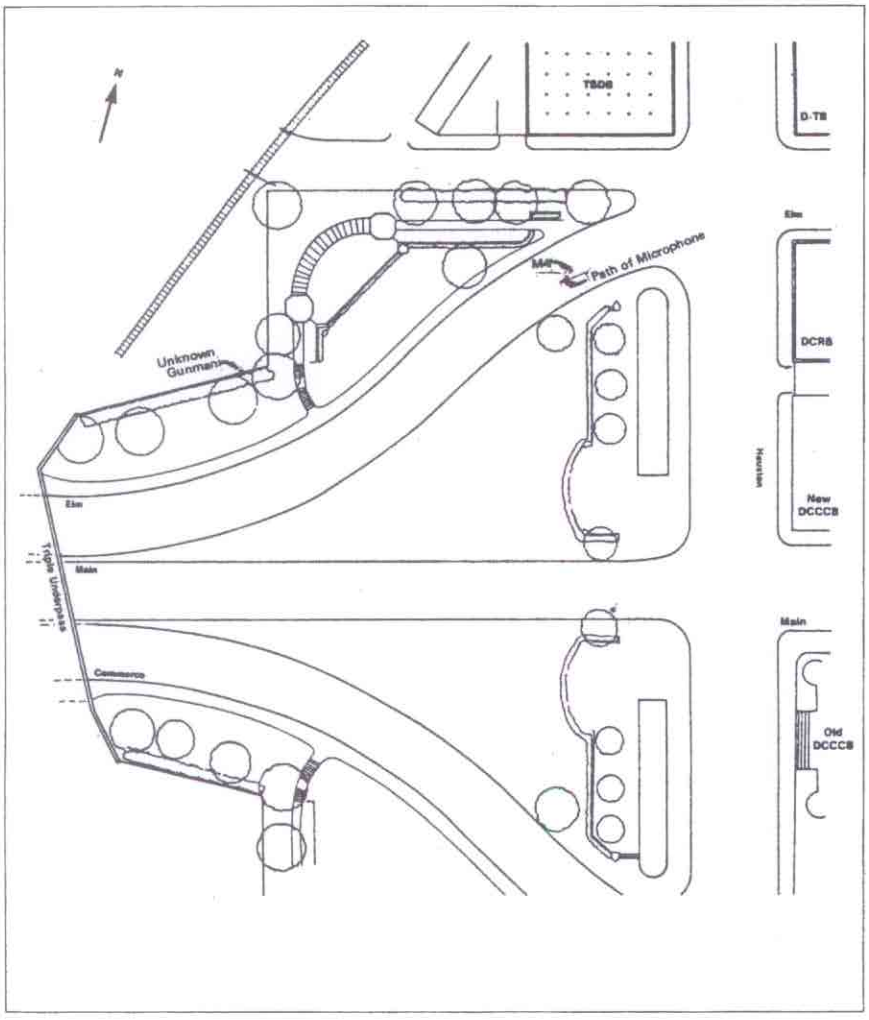
The first method cannot be used to validate the designated impulsive information originated in Dealey Plaza, since other sounds during the pertinent portion either did not originate from Dealey Plaza or their origin is unknown. The two reports to the HSCA reflect that a carillon bell is heard approximately 7 seconds after the last gunshot (no known carillon bells have been located in the vicinity of Dealey Plaza) and that there are voice signals from other police transmitters outside Dealey Plaza. These signals are sometimes too faint to be understood, sometimes the voices are loud but distorted, and sometimes they are quite understandable. No sounds are heard on the recording that would reflect that the specific information originated in Dealey Plaza, such as crowds cheering, recognizable voices, etc. This method does not show that the designated patterns originated from Dealey Plaza, and in fact, reflects information to the contrary.

The second method using the alleged uniqueness of the designated sounds, as applied by Weiss and Aschkenasy, also cannot validate that the impulsive information is from Dealey Plaza. Weiss and Aschkenasy stated that "if we now assume that the sound source [the gun] and the listener are located in a typical urban environment, with a number of randomly spaced echo-producing structures, it is possible to see that the pattern of sounds a listener will hear will be complex and unique for any given pair of gun and listener locations."[18] Other than explaining this statement in more detail, they do not provide any empirical or theoretical data to prove this uniqueness.

"The analysis in the Greensboro investigation clearly disproves the uniqueness assumption, as applied by BBN and Weiss and Aschkenasy, to show that the impulsive patterns originated in Dealey Plaza."

By locating the sound source in the general vicinity of the grassy knoll and the listener in the approximate location of the motorcycles in the Presidential motorcade, Weiss and Aschkenasy computed the expected delay times for different echo paths using string on the topographical survey map of Dealey Plaza. The echo delay times occur because it takes a longer period of time for a sound to travel from the sound source to a reflecting surface and to the listener than to go directly from the sound source to the listener. By shifting the sound source and listener locations slightly, they computed the best match with the impulsive pattern on the DPD recording by using a statistical technique.

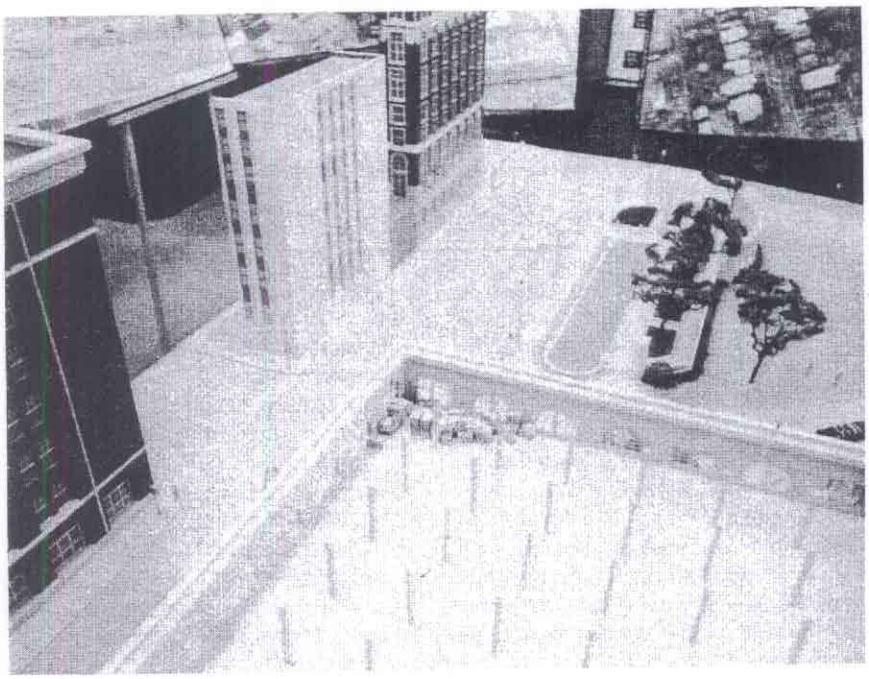
In November 1979, a violent confrontation occurred between members of the Ku Klux Klan, the Nazi Party, and the Communist Workers Party in a residential area of Greensboro, N.C., in which five people were killed. Using professional equipment, local TV personnel on the scene filmed and video taped the events as they happened, including known gunshots and other impulsive sounds that were not gunshots. One of the known gunshots in this matter was compared by FBI acoustical experts to the alleged grassy knoll shot, using the same statistical technique used by Weiss and Aschkenasy. The comparison found a very close match between the gunshots; however, the statistical significance could not be accurately determined.



Dealey Plaza

Aschkenasy stated in his oral testimony that if another sound pattern was found that matched the designated pattern on the DPD recording, he ". . . would expect to find . . . a replica of Dealey Plaza at that location. That's the only way that it can come out." [19] Dealey Plaza is an urban area with small parks, tall buildings, and a number of intersecting wide streets; the residential area in Greensboro has two narrow streets meeting in a "T" intersection, one- and two-story buildings, and small residential lots with fences. The residential area in Greensboro, N.C., is definitely not a replica of Dealey Plaza.

The analysis in the Greensboro investigation clearly disproves the uniqueness assumption, as applied by BBN and Weiss and Aschkenasy, to show that the impulsive patterns originated in Dealey Plaza. The unplanned occurrence of a gunshot in a residential section of Greensboro, N.C., 16 years after the Kennedy assassination produces a close match with the designated pattern on the DPD recording that is allegedly the gunshot from the grassy knoll. It is probable then to



expect that many of the urban areas within range of the DPD recording system could produce numerous sets of sound sources and microphone locations that would have a very high correlation when compared with the patterns on the DPD recording.

The third method to determine that the information came from Dealey Plaza is by eyewitnesses who can testify that a DPD motorcycle microphone was stuck open in Dealey Plaza on channel 1 and that the information from this particular microphone was being received and exclusively recorded at DPD Headquarters. No conclusive testimony to support this eyewitness method was presented to the HSCA.

According to the FBI review, "BBN, Weiss and Aschkenasy did not prove that the information on the DPD recording during the Presidential assassination on November 22, 1963, originated in or very near Dealey Plaza, Dallas, Texas." [20]

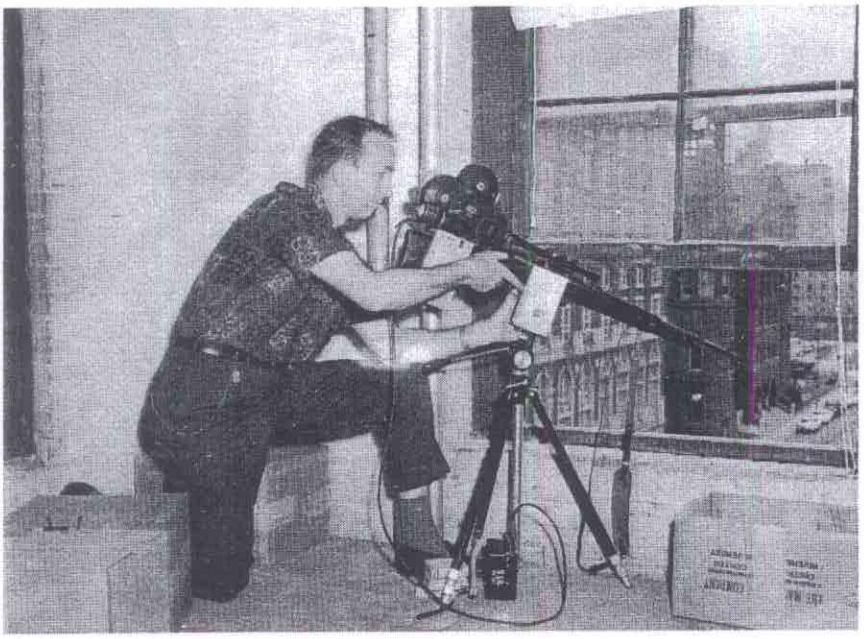
The second basic premise requires proof that the impulsive patterns analyzed actually represent gunshot sounds. To prove that a particular sound is a gunshot blast, some unique characteristics must be found that differentiate a gunshot blast from other sounds, especially ones that are impulsive. Weiss and Aschkenasy stated in their written report that "the most effective and most reliable" characteristic to determine if a sound is a gunshot and not some other like sound is the pattern of the muzzle blast echoes. Contradicting the written report, Weiss in oral testimony before the HSCA on December 29, 1978, stated that ". . . not so much the echo pattern as the evidence of a [supersonic] shock waves . . ." would differentiate a gunshot from other impulsive sounds.[21] And again contradicting themselves, Weiss and Aschkenasy stated in their written report that they made no serious examination to determine if there was a shock wave present before the designated pattern on the DPD recording. It is not possible to determine from the above which method, if any, Weiss and Aschkenasy used to determine if an impulsive pattern uniquely represents a gunshot blast.

If Weiss and Aschkenasy used the pattern of echoes as the best characteristic to determine if any impulsive sound is a gunshot, their theory fails. Everyone has had experiences where other impulsive sounds, like vehicular backfires and firecrackers, also produce echoes off buildings, vehicles, hills, etc. Scientific literature also states that all sounds, especially impulsive ones, produce diffractions and reflections or echoes off hard surfaces.

If Weiss and Aschkenasy used the presence of a shock wave as the preferred characteristic to determine if an impulsive sound is a gunshot, their theory again fails. Analysis in the Greensboro, N.C., examination determined that to detect a shock wave accurately is very difficult, even under high quality forensic conditions, since the shock wave itself produces a set of echoes which combine and change many of the characteristics of the muzzle blast sound signal. Under the poor conditions of the DPD recording, making any statements concerning the shock wave would be extremely questionable. This may be why Weiss and Aschkenasy decided not to comment on the possible presence of a shock wave in their written report. BBN testimony before the HSCA on December 29, 1978, stated that there is a 75- to 80-percent chance that a shock wave exists before the distorted waveform examined by Weiss and Aschkenasy on the DPD recording. Again, the distorted waveform examined on the DPD recording probably cannot support even this lower percentage estimate.

Left: Model showing position of alleged assassin in the Texas School Book Depository.

Below: The re-enactment.



According to the FBI's review, there is no conclusive proof provided by BBN or Weiss and Aschkenasy that the four patterns on the DPD recording represent gunshot blasts and not some other sounds or electrical impulses produced internally by the DPD radio system, that the impulsive sounds originated in or very near Dealey Plaza, or that the sounds represent gunshot blasts involved in the assassination of President Kennedy. Therefore, the HSCA's finding that "scientific acoustical evidence establishes a high probability that two gunmen fired at President John F. Kennedy" must be considered invalid.[22]

The FBI's review found numerous other problem areas and inconsistencies in the reports of BBN and Weiss and Aschkenasy.

First of all, in their written report, Weiss and Aschkenasy state that "impulse peaks that are less than 1 millisecond (1/1000 of a second) apart are considered to be part of the same impulse."[23] However, in the same report, they list separate impulses at 19.3 and 20.1 milliseconds, which are only 0.8 millisecond apart.

Second, the report of BBN visually shows the considerable changes that occur to the sound of a gunshot blast transmitted and recorded by a police radio system similar to the one used by the DPD in 1963. This considerable change in the recorded sound pattern is such that accurate analysis of any impulsive sounds through this system would be very difficult. Also, no known microscopic examination of the original DPD Dictabelt had been conducted to determine if any of the patterns analyzed may have been caused by surface imperfections and then distorted by the equipment's poor amplification system.

BBN eliminated a number of possibly useful impulsive patterns because they presupposed that gunshots originating on the grassy knoll and in the TSBD were aimed at President Kennedy and that these gunshot sounds were transmitted by a DPD motorcycle microphone located in the Presidential motorcade. One pattern was not further analyzed because it would represent a gunshot ". . . fired in a direction opposite to that of the logical target."[24] Another pattern was eliminated because it occurred only 1.05 second later than an earlier alleged gunshot impulse and Oswald's rifle could not be fired that rapidly. BBN did not consider whether a second gunman could have been at the TSBD location. Four impulsive patterns were eliminated because the specified motorcycle would probably be traveling too fast to be in the motorcade. However, the impulse could have been received by another motorcycle in the motorcade with an open microphone or in another part of the city. In other words, six other gunshots may have occurred in Dealey Plaza, according to the BBN analysis, though not necessarily aimed at President Kennedy or received by the microphone on the specified motorcycle.

And finally, Weiss and Aschkenasy, after determining that the error range for temperature and recorder speed variations was −3.0 percent to −7.0 percent, stated that a −4.3-percent correction gave the best match. Rigorous scientific research would not allow adjusting the error factor to make the best fit with the presupposed positions of a sound source and a listener.

" '. . . reliable acoustic data do not support a conclusion that there was a second gunman.' "

National Research Council Report

On May 14, 1982, the Committee on Ballistic Acoustics, Commission on Physical Sciences, Mathematics, and Resources, National Research Council (NRC), Washington, D.C., released their comprehensive report agreeing with the findings of the FBI review and also invalidating the HSCA conclusion.[25] According to the NCR:

> "The acoustic analyses [of BBN and Weiss and Aschkenasy] do not demonstrate that there was a grassy knoll shot, and in particular there is no acoustic basis for the claim of 95% probability of such a shot.
>
> "The acoustic impulses attributed to gunshots were recorded about one minute after the President had been shot and the motorcade had been instructed to go to the hospital.
>
> "Therefore, reliable acoustic data do not support a conclusion that there was a second gunman." [26]

The NRC determined that an analysis of the DPD channel 1 recording presents serious problems. The ambient noise level is high, the location of the open microphone is unknown, some background sounds are difficult to interpret, absence of certain expected sounds is difficult to explain, and the transmitting and recording systems altered the acoustical signals. Also, the HSCA studies were limited by funds and fixed deadlines, resulting in the omission of a number of important tests to verify the analysis procedures and the interpretations.

The NRC stated that since the recorded acoustic impulses are similar to radio static, attempts to represent them as gunshot sounds depended on echo analyses. However, because desirable control tests were omitted, the analyses were made using a subjective selection of impulse peaks. This leads to serious errors being made in statistical calculations, faulty statistical conclusions, and analysis methods that were untested at high levels of background noise. Therefore, for these and other reasons, the NRC concluded that the acoustic analyses of BBN and Weiss and Aschkenasy do not show that there was a grassy knoll gunshot. This decision by the NRC was reached prior to other more conclusive evidence reflecting that the alleged grassy knoll impulses were recorded on channel 1 approximately 1 minute after the actual assassination.[27]

According to BBN, there was a 50-percent probability of a gunshot being fired from the grassy knoll. However, even this statement was based on questionable assumptions and incorrect computations which were later used to justify the more detailed analysis of Weiss and Aschkenasy. The echo technique used by Weiss and Aschkenasy would at first appear to increase the credibility of the grassy knoll gunshot hypothesis; however, the NRC stated that the impulses identified by BBN were completely different from those analyzed by Weiss and Aschkenasy by more than 200 milliseconds (or more than 200 feet on the Dealey Plaza map).[28] Thus, there is a very serious problem in that the BBN analysis missed the pattern that Weiss and Aschkenasy used for their conclusion.

For its analysis BBN did not always select the strongest impulses. For unknown reasons, large impulses were ignored while impulses near the noise level were retained. There are considerably more impulses that are omitted by the BBN classification than there are ones analyzed as probable gunshot echoes. Since the results of statistical analysis are highly dependent on the impulse selection, it is critical that the technique used to distinguish noise from gunshot impulses be set forth in detail. However, this is not done in the HSCA reports. Furthermore, weak impulses on channel 1 are often selected to correspond to strong impulses in the test patterns and vice versa.

Although the results of the BBN analysis are supported by some "interpretations of photographic evidence as being consistent with a motorcycle in the procession at approximately the position indicated by their analysis, it is by no means certain that this was the motorcycle with the open microphone, that its radio was improperly tuned to Channel 1, that the open

microphone was even in Dealey Plaza, or that the relative times of the four sets of impulses studied by [BBN and Weiss and Aschkenasy] were consistent with the three known actual shots. There is important evidence to the contrary on all four of these points that should not be ignored." [29]

In his paper on the assassination of President Kennedy, Capt. James Bowles, Radio Dispatcher Supervisor of the DPD in 1963, states that the motorcycle with the open microphone was not part of the Presidential motorcade in Dealey Plaza, but was at the police command post near the Trade Mart during the assassination.[30] He relies on a subjective review of the motorcycle engine sounds (both before and after the assassination shots), the lack of crowd noises on DPD channel 1 (which are clearly heard on channel 2), the incorrect timing of the siren sounds after the assassination, voice transmissions, interviews with police officers, and the fact that all motorcycles in the motorcade were to be tuned to channel 2, not channel 1. Because of the questions posed by Bowles and others, serious doubts were raised about whether the motorcycle with the open microphone was in Dealey Plaza, an absolutely necessary requirement for the BBN conclusion.

> "No siren sounds are heard on Channel I at a time when they should have been heard by an open microphone in the motorcade; sirens are not heard for approximately two minutes after the impulses attributed by [BBN and Weiss and Aschkenasy] to assassination shots, following which clear and unambiguous sounds from a group of sirens occur on Channel I. The sirens seem to come from a group of at least 3 vehicles with the intensity of the sound first increasing and then decreasing. This is consistent with sirens heard at a stationary point if the presidential motorcade had passed close by. It is not the siren sound expected if a motorcycle with a stuck button had been part of the presidential motorcade. In the first quarter mile of the trip to the hospital, the presidential motorcade encountered a complex pattern of underpasses, roads and ramps. . . . But there is no trace of a siren sound in Channel I during this interval of time. This initial long absence of any indication of siren sounds, followed by the pattern of loud and clear sounds of several sirens passing by, suggests that the radio transmitter with the stuck button was not part of the presidential motorcade. This radio transmitter may have been on a motorcycle parked somewhere, perhaps, as suggested by James Bowles, at the Police Command Post near the Trade Mart, where it would be natural for there to be adjacent police radios tuned to different channels. . . ." [31]

The NRC also found the statistical method used to obtain the 95-percent or better probability of a grassy knoll gunshot to be completely invalid, due to misinterpretations of probability theory by BBN and Weiss and Aschkenasy. ". . . no member of the [NRC] Committee on Ballistic Acoustics was convinced . . . that there was a grassy knoll shot. The members of the Committee reached their initial negative conclusion *prior to* the availability of the sound spectrograms and event timing. . . ." [32]

Steve Barber of Mansfield, Ohio, wrote to the NRC committee that there are clear examples in which voice information recorded on channel 2 were heard on channel 1 as well. This can be explained by having the motorcycle with the open microphone near another radio receiving a transmission on channel 2. In addition, there are transmissions by the police

"Analysis of recorded gunshot sounds . . . is a complex process requiring specialized laboratory equipment, a practical and theoretical knowledge of ballistics, and a commonsense approach.

radio dispatcher simultaneously on channels 1 and 2. Both kinds of so-called "crosstalk" are often clearly understandable. Identical portions of speech on both channels 1 and 2 permit precise time synchronizations between specific portions of the two channels. However, time synchronizations would not apply to the complete recordings, because channel 1 ran continuously during the assassination while channel 2 was operated intermittently. Thus, matching transmissions could be used to determine the relative timing between many of the same events on channels 1 and 2.[33]

Matching sections on both channels were identified by Barber. Although four of the matching sections are distinct, they occur several minutes after the assassination and are of communications that were connected with the followup of the shooting. They do, however, clearly reveal crosstalk between the two channels.

To fix the time of the tape section analyzed by BBN and Weiss and Aschkenasy, two events are decisive. The first is a 4-second portion of the tape overlapping the presumed third and fourth BBN shots on channel 1; the second is a transmission occurring several minutes after the assassination which is clearly recognizable on both channels.

With regard to the first crucial event, the 4-second fragment, Barber identifies a phrase beginning "hold everything" as being identical to a statement clearly recorded on channel 2, which was " '. . . hold everything secure until the homicide and other investigators get here. . . .' " [34] "The significance of this proposed match is that the section on Channel I is concurrent with the last two of the conjectured [BBN] shots, whereas on Channel II that communication is part of a clear sequence of emergency communications that followed the shooting and occurred approximately one minute after the assassination. It is, in fact, part of Sheriff Decker's instructions to his men in response to the assassination." [35] If this time synchronization is correct, the shots postulated by BBN and Weiss and Aschkenasy could be proven to be unrelated to the gunshot sounds of the assassination, since the section of the channel 1 recording analyzed would correspond to a time period after the assassination.

"You want me . . . Stemmons" is the second transmission providing a common reference point for timing events on both channels. It was used to determine whether the recording of the selected conjectured shots occurred before or after the motorcade was instructed to go to the hospital.[36]

Under the supervision of the NCR committee members, spectrograms (voiceprints) of the tape recordings were prepared, since portions were badly garbled and of poor audio quality. This was done to diminish the power of suggestion or cueing effect that often affects listeners, convincing them to hear what they have been coached to hear. ". . . a sound spectrogram with a similar pattern for the '. . . hold everything . . .' phrase on Channel I was also made from a tape supplied by [BBN] . . .; later sound spectrograms were also made from new high quality magnetic tape copies of the original Channel I Dictabelt and Channel II Audiograph disc." [37]

The NRC then visually compared sound spectrograms of the "You want me . . . Stemmons" transmissions occurring several minutes after the assassination. "The match is clear, and establishes unambiguously that identical portions of speech can be identified on both channels." [38] Comparison of the spectrograms of the "hold everything" sections also resulted in an excellent match, which is very striking when it is realized that only the first second of the "hold everything" phrase can be heard clearly on channel 1, yet the spectrograms have numerous identical features for the entire 3.5-second transmission. It is apparent from the text of the transmissions and from their amplitudes that a signal from channel 2 was duplicated onto channel 1 and not the reverse.

"The sound spectrograms present much more convincing evidence in the present case than in their application to speaker identification. There, words spoken at different times, supposedly by the same speaker, are compared and a trained interpreter is often required to explain why the subjective match is significant. In the present case, the need is to identify two *identical* messages extending over a three and a half second interval. Not only must individual parts of the two sound spectra be alike but they must occur at exactly correct time intervals and with exactly matching frequencies. The existence of these required time and frequency correlations between the two channels imposes rigid constraints on the messages to be matched." [39]

The NRC committee used three techniques in addition to the visual inspection to determine whether the sound spectrograms of channels 1 and 2 contained the same radio transmissions. The first method compared 27 features between the spectrograms to verify that the timing sequence is correct; the second technique used discrete frequencies to compare recording speed; and the third used a sophisticated computer statistical comparison.

The results of this analysis revealed "overwhelming evidence that the 'hold everything' sections of the two recordings are traceable back to a single acoustic signal from Channel II."[40] Therefore, the match of information between these two recordings is "conclusive evidence that the events analyzed by [BBN and Weiss and Aschkenasy] were not the assassination shots, since we know from Channel II that the 'hold everything' transmission was made at least 50 seconds after the [Police] Chief instructed the motorcade to 'Go to the hospital.'"[41]

Conclusion

Analysis of recorded gunshot sounds, or of alleged gunshot sounds, is a complex process requiring specialized laboratory equipment, a practical and theoretical knowledge of ballistics, and a commonsense approach. The HSCA analyses performed in the Kennedy assassination illustrates that highly technical examinations performed without a review of all available information are often incorrect, or at least, misleading. The FBI's limited review and the NRC committee's analysis in the assassination reflect, however, that accurate identifications of gunshot sounds are possible in certain situations. The FBI has developed the techniques to perform state-of-the-art examinations of impulsive sounds, like gunshots, but only if forensic conditions allow. **FBI**

Footnotes

[16] *Review Requested by the Department of Justice of the Acoustical Reports Published by the House Select Committee on Assassinations,* Technical Services Division, Federal Bureau of Investigation, November 19, 1980, p. 2.

[17] FBI *Review,* p. 13.

[18] FBI *Review,* p. 14.

[19] FBI *Review,* p. 15.

[20] FBI *Review,* p. 16.

[21] FBI *Review,* p. 17.

[22] FBI *Review,* p. 19.

[23] FBI *Review,* p. 20.

[24] FBI *Review,* p. 20.

[25] The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the academy's purposes of furthering knowledge and of advising the Federal Government. The council operates in accordance with general policies determined by the academy under the authority of its congressional charter of 1863, which establishes the academy as a private, nonprofit, self-governing agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the Government, the public, and the scientific and engineering communities. It is administered jointly by both academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences. The members of the committee were Norman F. Ramsey—Chairman (Harvard University), Louis W. Alvarez (University of California), Herman Chernoff (Massachusetts Institute of Technology), Robert H. Dicke (Princeton University), Jerome I. Elkind (Xerox Palo Alto Research Center), John C. Feggeler (Bell Telephone Laboratories), Richard L. Garwin (IBM Corporation), Paul Horowitz (Harvard University), Alfred Johnson (Bureau of Alcohol, Tobacco and Firearms), Robert A. Phinney (Princeton University), Charles Rader (Massachusetts Institute of Technology), and F. Williams Sarles (Trisolar Corporation).

[26] *Report of the Committee on Ballistic Acoustics,* Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C., 1982, p. 2.

[27] *Report of the Committee on Ballistic Acoustics,* p. 1.

[28] *Report of the Committee on Ballistic Acoustics,* p. 13.

[29] *Report of the Committee on Ballistic Acoustics,* pp. 13–14.

[30] James C. Bowles, *The Kennedy Assassination Tapes, A Rebuttal to the Acoustical Evidence* (copyrighted and unpublished).

[31] *Report of the Committee on Ballistic Acoustics,* pp. 14–15.

[32] *Report of the Committee on Ballistic Acoustics,* p. 17.

[33] *Report of the Committee on Ballistic Acoustics,* p. 18.

[34] *Report of the Committee on Ballistic Acoustics,* pp. 18–19.

[35] *Report of the Committee on Ballistic Acoustics,* p. 19.

[36] *Report of the Committee on Ballistic Acoustics,* p. 19.

[37] *Report of the Committee on Ballistic Acoustics,* p. 20; for further information on sound spectrograms see Bruce E. Koenig, "Speaker identification," FBI Law Enforcement Bulletin, January and February 1980.

[38] *Report of the Committee on Ballistic Acoustics,* p. 20.

[39] *Report of the Committee on Ballistic Acoustics,* p. 21.

[40] *Report of the Committee on Ballistic Acoustics,* p. 25.

[41] *Report of the committee on Ballistic Acoustics,* p. 25.